

Table of Contents

I. EXECUTIVE SUMMARY	3
II. INTRODUCTION	5
III. OBJECTIVES	5
IV. METHODS	6
A. Study Area	6
B. Cancer	6
C. Down syndrome	8
1. Case definition	8
2. Case ascertainment	8
3. Prevalence	9
D. Geographic Analysis	9
V. RESULTS	10
A. Cancer Incidence Analysis	10
1. Cancer Incidence in the Deerfield River Valley, 1982-1992	10
2. Temporal Analysis of Cancer Incidence in the Deerfield River Valley	10
3. Cancer Incidence in Individual DRV Towns	10
4. Smoking Status	13
5. Occupation	15
6. Geographic Distribution	15
B. Down Syndrome Prevalence Analysis	17
1. Case Description	17
2. Geographic and Temporal Distribution	17
3. Prevalence	18
C. Environmental Data	18
1. Radionucleides Sampling	18
2. Tritium Exposures	19
3. 21E and TRI Sites	19
VI. DISCUSSION	20
A. Cancer	20
B. Down syndrome	21
1. Studies of Radiation Exposures and Down Syndrome	23
VII. LIMITATIONS	24
VIII. CONCLUSIONS	25
IX. RECOMMENDATIONS	26
X. REFERENCES	27

Note: At this time, the Center for Environmental Health is unable to provide these figures and tables (listed below) via the Internet. If you are interested in obtaining more information, please contact us at 617/ 624-5757. Thank you for your cooperation.

FIGURES

FIGURE 1A: Deerfield River Valley, Massachusetts
FIGURE 1B: Deerfield River Valley With Can Boundaries, Massachusetts
FIGURE 2A: Known Smoking Status Of Selected Cancers During 1982-1992, Deerfield River Valley, Massachusetts
FIGURE 2B: Known Smoking Status Of Selected Cancers During 1982-1992, Massachusetts
FIGURE 2C: Smoking Status Of Selected Cancers During 1982-1992, Deerfield River Valley, Massachusetts
FIGURE 2D: Smoking Status Of Selected Cancers During 1982-1992, Massachusetts
FIGURE 3: Resolution Of Reported Down Syndrome Cases In The Deerfield River Valley, Ma
FIGURE 4: Down Syndrome Children By Year Of Birth, 1980-1990
FIGURE 5: Location Of 21e And Tri Sites In The Deerfield River Valley

TABLES

TABLE 1A: Cancer Incidence In The Deerfield River Valley Towns Combined, 1982-1992
TABLE 1B : Cancer Incidence In The Deerfield River Valley Towns Combined, 1982-1986 & 1987-1992
TABLE 2a: Cancer Incidence In Ashfield, Ma 1982-1992
TABLE 2b: Cancer Incidence In Ashfield, Ma 1982-1986 & 1987-1992
TABLE 3a: Cancer Incidence In Buckland, Ma 1982-1992
TABLE 3b: Cancer Incidence In Buckland, Ma 1982-1986 & 1987-1992
TABLE 4a: Cancer Incidence In Charlemont, Ma 1982-1992
TABLE 4b: Cancer Incidence In Charlemont, Ma 1982-1986 & 1987-1992
TABLE 5a: Cancer Incidence In Conway, Ma 1982-1992
TABLE 5b: Cancer Incidence In Conway, Ma 1982-1986 & 1987-1992
TABLE 6a: Cancer Incidence In Deerfield, Ma 1982-1992
TABLE 6b: Cancer Incidence In Deerfield, Ma 1982-1986 & 1987-1992
TABLE 7a: Cancer Incidence In Florida, Ma 1982-1992
TABLE 7b: Cancer Incidence In Florida, Ma 1982-1986 & 1987-1992
TABLE 8a: Cancer Incidence In Hawley, Ma 1982-1992
TABLE 8b: Cancer Incidence In Hawley, Ma 1982-1986 & 1987-1992
TABLE 9a: Cancer Incidence In Heath, Ma 1982-1992
TABLE 9b: Cancer Incidence In Heath, Ma 1982-1986 & 1987-1992
TABLE 10a: Cancer Incidence In Monroe, Ma 1982-1992
TABLE 10b: Cancer Incidence In Monroe, Ma 1982-1986 & 1987-1992
TABLE 11a: Cancer Incidence In Rowe, Ma 1982-1992
TABLE 11b: Cancer Incidence In Rowe, Ma 1982-1986 & 1987-1992
TABLE 12a: Cancer Incidence In Shelburne, Ma 1982-1992
TABLE 12b: Cancer Incidence In Shelburne, Ma 1982-1986 & 1987-1992
TABLE 13: 1980-1990 Down Syndrome Cases By Year Of Birth And Residence At Birth
TABLE 14: Crude Prevalence Of Down Syndrome, 1980-1990
TABLE 15: Down Syndrome Cases By Maternal Age Compared To The Expected Number Of Cases, 1980-1990: Drv (11 Towns)
TABLE 16: Down Syndrome Cases By Maternal Age Compared To The Expected Number Of Cases, 1980-1990: Drv (5 Towns: Ashfield, Buckland, Charlemont, Deerfield, Shelburne)

I. EXECUTIVE SUMMARY

In February 1997 the Massachusetts Department of Public Health (MDPH) under a cooperative agreement with the Agency for Toxic Substances and Disease Registry (ATSDR) completed a draft Health Consultation entitled, *Cancer Incidence and Down Syndrome Prevalence in the Deerfield River Valley*. The public comment period for the Consultation ended in May 1997. The purpose of this summary is to provide the reader with the background and conclusions for the original study as well as for the follow-up investigations.

The primary area of citizen concern focused on the nuclear power station owned by Yankee Atomic Electric Company located in Rowe, Massachusetts. The community was specifically concerned that historic releases of radioactive effluent into the Deerfield River and surrounding environment may be related with increases in cancer incidence and Down syndrome in the DRV area. In response to these concerns, the MDPH conducted a descriptive epidemiological study involving 11 towns located in the DRV. The investigation yielded the following conclusions:

The available data did not suggest that residents of the DRV experienced excessive rates of cancer during the period 1982-1992. For the majority of cancer types evaluated, cancer cases occurred at the same rate or a lower rate than would have been expected based on statewide cancer incidence. No unusual temporal or geographic patterns were observed in any of the 11 towns evaluated, which would suggest an environmental factor is related to the incidence of cancer in this area.

No unusual geographic pattern of cancer incidence was observed with respect to proximity to the Deerfield River for any of the 10 cancer types evaluated. The majority of cases were located greater than one mile from the river at the time of diagnosis. No apparent clustering or concentration of cases was observed in relation to 21E sites or TRI sites. Moreover, there was no apparent geographic pattern of any one cancer type or within any individual town located within the confines of the CAN boundary.

An elevation was observed in breast cancer among females in the town of Shelburne during the years 1982-1994. Although this elevation was statistically significant, no geographic pattern or concentration of cases was observed in the town during any of the time periods evaluated. However, the incidence of this cancer appears to have increased over time in Shelburne and was more pronounced during the later time period 1987-1992.

The age distribution of breast cancer cases revealed that the majority of cases (69%) were diagnosed in women greater than age 50. The incidence of breast cancer appeared highest among women age 40 to 44 years and in women over the age of 85. The majority of the cases occurring in these two age groups were diagnosed at an earlier stage of the disease. In addition, examination of the temporal pattern exhibited by these cases shows that they were diagnosed in different years during 1987 to 1994.

An evaluation of breast cancer staging information indicates that the majority of breast cancer cases in Shelburne were diagnosed at an early stage, rather than a later stage of the disease. Since breast cancer screening improves detection of breast cancer at an early stage of the disease, this finding suggests that women in Shelburne had access to and utilized breast cancer screening

The town of Shelburne displayed lower socioeconomic characteristics than the state of Massachusetts. This finding contradicts the research indicating that higher

socioeconomic status is related to factors, which increase a women's risk of developing breast cancer. However, these socioeconomic markers describe the entire town of Shelburne and may not be representative of the population at risk.

In Shelburne, the mean age at first full term pregnancy increased from 26 to 29 years and parity decreased from 1975 to 1990, primarily due to a decrease in first childbirths. These data suggest that reproductive factors that have been associated with an increased risk of breast cancer may have influenced the current rate of breast cancer in the area.

Although NHL was significantly elevated among women in Deerfield during 1982-1992, the elevation was based on approximately five excess cases. Most of the elevation occurred during 1987-1992 and the number of excess cases is relatively small. The geographic distribution of NHL incidence in Deerfield did not reveal any unusual concentration of cases. Review of available information for individuals diagnosed with NHL revealed that six out of eleven cases had personal risk factors that have been shown to be associated with an increased risk of developing NHL (i.e., occupation and smoking). Therefore it is likely that these factors may have played a role in the development of NHL for some individuals. In addition, review of residential histories for the NHL cases indicates that only 50% of the NHL cases in Deerfield were long-term residents of the town. Given the latency period for the development of cancer and additional information about the cases regarding other risk factors, it is not likely that residence alone is a primary factor in the development of NHL in this area

Elevations in multiple myeloma incidence in the DRV were not statistically significant during 1982-1992, and the cases were widely spread throughout the region. The incidence pattern of multiple myeloma cases in the DRV was consistent with the established epidemiology for this cancer. Review of occupational histories for multiple myeloma cases diagnosed in the DRV did not reveal any occupations among the cases that have been suggested as related to an increased risk of developing this cancer.

Based on comparisons with national data, the prevalence of Down syndrome in the DRV during the period 1980-1990 was elevated. This elevation is based upon eight confirmed cases. The prevalence of DS was significantly elevated when compared to the prevalence reported in California.

A spatial cluster of 3 children with DS occurred in Buckland during the 1980s. However, evaluation of the time frame of birth for all 8 children did not indicate an unusual pattern (e.g., a temporal cluster).

Although some epidemiologic studies have associated the occurrence of DS with exposure to ionizing radiation, the association is still debated. In addition, exposure to tritium has not been found to be associated with the occurrence of Down syndrome. Evaluations of the potential exposure of DRV residents to tritium present in the Deerfield River concluded that the estimated dose of tritium received from the Deerfield River as a result of operations from the Yankee Rowe nuclear power station was several orders of magnitude lower than the dose received from all natural sources of radiation.

The environment has not been ruled out as a potential factor in the development of cancer and birth defects in residents of the DRV. However, based on health risk assessments conducted by other researchers and the available data reviewed in this report, it seems unlikely that tritium exposures (and based on the available environmental data, other environmental exposures) to DRV residents would have resulted in an increase in the occurrence of cancer or Down Syndrome.

As a result of these findings, the following recommendations have been made:

Although the prevalence of DS in the DRV was elevated, no unusual geographic pattern was observed among these children in relation to the environmental data reviewed that seems to explain the occurrence of DS in the DRV. Maternal age did not appear to explain the increased prevalence of DS. A seasonal pattern was observed among these cases. After discussion with the U.S. Centers for Disease Control (CDC), the MDPH recommends that the conduct of further investigations of potential individual factors that may be related to the occurrence of DS among these children be discussed with the families of children with DS, the CDC, and the CAN. Should these groups determine that follow-up investigations would lead to a better understanding of DS among these children, the MDPH recommends that such additional investigation be conducted in cooperation with the Centers for Disease Control, National Center for Environmental Health.

The MDPH/BEHA will continue to monitor cancer incidence rates in the 11 DRV towns through the Massachusetts Cancer Registry.

In view of the fact that the statistically significant elevation in female breast cancer incidence observed in Shelburne during the time period 1982-1994 was due to an increase in incidence during the later period (1987-1994), the Community Assessment Unit will continue to monitor the incidence of breast cancer in this town.

Definitive information about the role of environmental factors in breast cancer is not currently available. However, studies are underway to evaluate potential links between breast cancer and environmental factors. The MDPH is currently conducting a large scale study on Cape Cod evaluating the role that environmental factors may have played in breast cancer incidence in that area. This work is being performed through a contract with the Silent Spring Institute. In addition, a second large-scale study is being conducted in Berkshire County where opportunities for exposure to PCBs have clearly occurred. If new information regarding the environment and breast cancer is gained through these research initiatives, the MDPH will consider this information and its relevance to the DRV community.

II. INTRODUCTION

In response to concerns expressed by The Citizen's Awareness Network (CAN) regarding possible elevations in cancer and birth defects near the Deerfield River and the potential relationship to environmental factors, staff from the Community Assessment Unit (CAU) of the Massachusetts Department of Public Health, Bureau of Environmental Health Assessment (MDPH, BEHA) conducted an evaluation of cancer incidence and DS prevalence in the Deerfield River Valley (DRV). The primary concern is the proximity of the nuclear power station owned by the Yankee Atomic Electric Company and located on the Deerfield River south of the Sherman Dam in Rowe, Massachusetts. As part of its normal operation, the Yankee Nuclear Power Station (or Yankee Rowe) has historically discharged effluent into the Deerfield River [Kahn et al. 1971]. A component of the effluent was a radioactive product known as tritium. The CAN is specifically concerned that historic releases of tritium to the Deerfield River and possibly the surrounding environment may be associated with increases in cancer and Down syndrome (DS) in the Deerfield River Valley area.

III. OBJECTIVES

The objectives of this investigation were to:

determine whether elevated rates of cancer exist in the DRV area as compared to the state of Massachusetts;

determine whether an elevated prevalence of DS exists in the DRV area;

evaluate temporal trends of cancer and DS in the DRV area;

analyze the geographic distribution of cancer and DS cases in relation to the Deerfield River; and

discuss the results in the context of the available information to determine whether further investigation is warranted and/or feasible.

IV. METHODS

A. Study Area

The Deerfield River is a tributary to the Connecticut River and is located in northwestern Massachusetts and southern Vermont. The river has a drainage basin area consisting of 664 square miles. Three hundred and forty-eight square miles are located within Massachusetts [Hansen et al. 1973]. The area of evaluation for this investigation includes 11 towns located in the Deerfield River Valley. These towns are: Ashfield, Buckland, Charlemont, Conway, Deerfield, Florida, Hawley, Heath, Monroe, Rowe, and Shelburne. With the exception of the towns of Ashfield, Heath and Hawley, all of these towns are located adjacent to the Deerfield River. These 11 towns were selected for evaluation based on concerns raised by the CAN. The CAN selected these towns because they are located in the valley and downriver from the Yankee Atomic power plant and because CAN believed they are the areas that have the greatest opportunity for exposure to air emissions from the power plant. Refer to Figure 1A for a map of the DRV area.

B. Cancer

Ten types of cancer were evaluated in this investigation. These include cancers of the bladder, breast, kidney, liver, lung, pancreas and thyroid, as well as leukemia, multiple myeloma and non-Hodgkin's lymphoma (NHL). Leukemia and cancers of the lung and thyroid were selected for evaluation based on their known potential sensitivity to ionizing radiation. The remaining cancers were included in order to address concerns raised by the CAN regarding suspected elevations in the incidence of these cancer types near the Deerfield River.

In order to evaluate cancer incidence, Standardized Incidence Ratios (SIRs) were calculated for the period 1982-1992 for each type of cancer for each of the 11 towns and for the 11 towns combined. SIRs were also calculated for the two time periods 1982-1986 and 1987-1992, in order to evaluate temporal trends in cancer incidence. SIRs were not calculated when fewer than five cases were observed. Available risk factor information, as reported to the Massachusetts Cancer Registry (MCR) (e.g., smoking status and occupation) was also reviewed for specific cancer types.

Cancer incidence data for the years 1982-1992 were obtained from the MCR. The MCR has been monitoring cancer incidence in the Commonwealth since 1982. The 11-year period 1982-1992 is the most recent for which complete data exist. To determine whether elevated numbers of cancer cases have occurred in the 11 towns, cancer incidence data were analyzed by age and sex to

compare the observed number of cancer cases in each town and in the 11 towns combined to the number that would be expected based on the statewide cancer experience.

In order to calculate incidence rates, it is necessary to obtain accurate population information. The population figures used in this analysis were interpolated based on 1980 and 1990 census data for each town [U.S. Department of Commerce 1980, 1990]. To estimate the population between census years, an assumption was made that the change in population occurred at a constant rate throughout the ten year interval between each census. From these calculations, 1987 population estimates were obtained for each of the 11 towns in the DRV. Population estimates for the year 1987 were used to calculate SIRs for each time period evaluated.

An SIR estimates the occurrence of disease in a population relative to what might be expected if the population had the same cancer experience as some larger population designated as "normal" or average. Usually, the state as a whole is selected to be the "normal" population.

Specifically, an SIR is the ratio of the observed number of cancer cases to the expected number of cases multiplied by 100. An SIR of 100 indicates that the number of cancer cases observed in the population being evaluated is equal to the number of cancer cases expected in the normal population. An SIR greater than 100 indicates that more cancer cases occurred than expected; an SIR less than 100 indicates that fewer cancer cases occurred than expected. Accordingly, an SIR of 150 is interpreted as 50% more cases than the expected number; an SIR of 90 indicates 10% fewer cases than expected.

Caution should be exercised, however, when interpreting an SIR. The interpretation of an SIR depends on both the size and the stability of the SIR. Two SIRs can have the same size but not the same stability. For example, an SIR of 150 based on two expected cases and three observed cases indicates a 50% excess in cancer, but the excess is actually only one case. Conversely, an SIR of 150 based on two hundred expected cases and three hundred observed cases represents the same 50% excess in cancer, but because the SIR is based upon a greater number of cases, the estimate is more stable. It is very unlikely that 100 excess cases of cancer would occur by chance alone.

To determine if the observed number of cases is significantly different from the expected number or if the difference may be due solely to chance, a 95% Confidence Interval (CI) is calculated [Rothman and Boice 1982]. A 95% confidence interval is the range of estimated SIR values that has a 95% probability of including the true SIR for the population. If the confidence interval range does not include the value 100, then the study population is significantly different from the "normal" population. "Significantly different" means there is less than five percent chance that the observed difference is merely the result of random fluctuation in the number of observed cancer cases. For example, if a confidence interval does not include 100 and the interval is above 100, then there is a significant excess in the number of cancer cases. Similarly, if the confidence interval does not include 100 and the interval is below 100, then the number of cancer cases is significantly lower than expected. If the confidence interval range includes 100, then the true SIR may be 100, and it cannot be concluded with sufficient confidence that the observed number of cases reflects a real cancer excess or deficit. Statistical significance is not assessed when fewer than five cases are observed.

The width of the confidence interval reflects the stability of the SIR estimate. For example, a narrow confidence interval (e.g., 103--115) means that the calculated SIR is probably close to the true SIR for the population. A wide interval (e.g., 85--450) means that the true SIR could be much lower than or much higher than the calculated SIR. This indicates an unstable statistic.

The observed number of cancer cases reported in the following sections for the DRV towns evaluated are in some instances slightly different from the observed number of cases shown in

the MCR report, *Cancer Incidence in Massachusetts 1982-1992 City and Town Supplement* [MDPH 1995]. The data contained in the MCR *City and Town Supplement* reflect information entered in the MCR computer files prior to the date this file was closed and made available for research. The data in this research file are constantly being quality controlled so that corrections may be made in subsequent reports. Occasionally, the research file may contain duplicate cases.

The data discussed in this report have been controlled for duplicate cases. The analyses account for duplicate cases by removing the duplicate cases while including multiple primary cancer cases. A multiple primary cancer case is defined by the MCR as a new cancer of the same histology as an earlier cancer, if diagnosed in the same primary site (or original location in the body) more than two months after the initial diagnosis [MDPH 1996]. Duplicate cases are additional reports of the same primary site cancer case. The decision that a case was a duplicate and should be excluded from the analyses was made by the MCR after consulting with the reporting facilities and obtaining additional information regarding the histology and/or pathology of the case.

C. Down syndrome

In order to obtain an estimate of the prevalence of Down syndrome (DS) in the DRV area, it was necessary to: 1) develop a case definition; 2) ascertain the number of children with DS in the 11 town area; and 3) compare to prevalence estimated from birth defect registry surveillance data.

1. Case definition

A DS case was defined as an infant who: (a) was a live birth and not a stillbirth, spontaneous abortion, or medical abortion; (b) was born during the time period 1980 through 1990; (c) had a mother with a verifiable residence in the DRV at the time of birth, and; (d) had a confirmed diagnosis of DS from any of the following sources: chromosome analysis, medical record indicators, vital records, outreach programs, and CAN reported cases.

The case definition was limited to live births to allow for a comparison of the prevalence of DS in the DRV to prevalence estimates cited in the literature, reported as the number of DS cases per number of live births. Chromosomal confirmation of DS alone was not a requirement of the case definition. If a child reported with DS met the case definition, then parental consent was obtained to participate in the investigation and to review medical records for the child to confirm the diagnosis of DS. Prior to 1980, the sources used for case ascertainment or confirmation were not available or not reliable. For example, the CAN provided MDPH with a list of cases diagnosed in the 1970's, after which staff surveyed several hospitals serving DRV residents. MDPH staff learned that cases diagnosed during the 1970s would be difficult, at best, to ascertain or confirm. Therefore, the temporal boundaries for the case definition were limited to the years 1980-1990.

2. Case ascertainment

At the time of this investigation (February 1997), Massachusetts did not have a birth defects registry or a coordinated reporting system to monitor the prevalence of DS or other congenital anomalies. Accurate data regarding the prevalence of DS statewide or for any specific town were therefore not available. As a result, several sources were used in order to identify children with DS. Birth certificates on file at the MDPH were reviewed for births occurring in the DRV area between the years 1980 and 1990. The MDPH Early Intervention Unit and the REACH Program in western Massachusetts were also contacted in an attempt to ascertain additional DS cases that may have been reported to these organizations. Children not identified through the birth certificate search or other sources were identified from a list of individuals reported to have DS submitted by the CAN.

Identification of individuals with DS through the search of birth certificates has proven unreliable. In Massachusetts, a pilot study which compared the reporting of all congenital anomalies among medical records and birth certificates for infants from seven hospitals found that birth certificates captured only 9% of congenital anomalies [Bingay, 1995]. The search of birth certificates in the 11 DRV towns for 1980-1990 identified five children with DS. Therefore, the MDPH used additional sources such as Early Intervention, REACH, and the CAN to enhance case ascertainment. Since information from these additional sources was not available prior to 1980, the case definition was restricted to the post-1980 time period, which allowed for more accurate and reliable case ascertainment.

3. Prevalence

Prevalence is defined as the total number of all individuals who have an attribute or disease at a particular time (or during a particular period) divided by the population at risk of having the attribute or disease at this point in time or midway through the period [Last 1988]. The prevalence of DS is typically reported as the number of DS cases per 1,000 live births. To estimate DS prevalence in the DRV area, the number of confirmed DS cases which occurred during 1980-1990 was divided by the number of live births recorded in the 11 DRV towns during the same time period. The prevalence of DS was also estimated for the five towns in which DS cases occurred. These towns include Ashfield, Buckland, Charlemont, Deerfield, and Shelburne.

Ideally, in order to determine if an excess of DS in the DRV area exists, the prevalence of DS in the DRV would be compared to the prevalence of DS designated in a comparison population (i.e., larger and more stable). Usually, Massachusetts is chosen as the comparison population. However, because Massachusetts does not currently have reliable data on statewide birth defects [Bingay 1995], prevalence data from the California Birth Defects Monitoring Program were used to estimate the expected number of children born with DS in the DRV area [CBDMP 1990]. California rates were considered more stable, as a result of data collection from 452,287 live births. The expected number of cases in the DRV was calculated by multiplying the prevalence of DS observed in California during the period 1983-1986 by the number of live births that occurred in the DRV during 1980-1990. The prevalence was adjusted for maternal age using the following age categories: <25, 25-29, 30-34 and 35+ years. In addition, 95% confidence intervals were calculated around the ratio of the observed to the expected number of DS cases [Rothman and Boice 1982].

D. Geographic Analysis

The geographic distribution of cancer and DS cases was determined using available information regarding place of residence reported at the time of diagnosis or birth. This information was compiled and evaluated using the computer mapping software MapInfo [MapInfo 1994]. The location and distribution of cancer and DS cases was evaluated based on distance to the Deerfield River. The geographic distribution of cases was also evaluated in relation to geographic boundaries of the DRV provided by the CAN (refer to Figure 1B) [CAN 1996]. This area is smaller than the 11 town study area but generally follows the topographic contours of the Deerfield River Valley and consists of approximately 130 square miles. As drawn, the boundary excludes most of the towns of Deerfield and Heath and portions of the remaining towns. The CAN constructed this boundary to represent the area with the greatest potential exposure to tritium via aerosolization from the Deerfield River and air emissions from the Yankee Rowe plant.

In several instances where address information did not include specific streets or street numbers, extensive efforts were made to research those cases using telephone books and residential lists issued within two years of an individual's diagnosis. In addition, CAU staff visited all of the towns evaluated in order to verify address locations and to locate more densely populated areas, and characterize the distribution and types of residences on major routes.

V. RESULTS

A. Cancer Incidence Analysis

1. Cancer Incidence in the Deerfield River Valley, 1982-1992

Residents of the DRV appear to have experienced cancer incidence comparable to the rest of the state during 1982-1992. With the exception of multiple myeloma, for most types of cancers the SIRs were about equal to or less than 100. However, multiple myeloma incidence in the 11 towns combined was elevated among males, females, and males and females combined. None of the observed elevations were statistically significant. Lung cancer occurred less often than expected. In fact, a nearly significant decrease in the incidence of lung cancer was observed during this time period. A slight elevation was noted in the incidence of thyroid cancer (7 observed/6.1 expected; SIR=115). This elevation was due to less than one excess case and was not statistically significant. These data are summarized in Table 1A.

2. Temporal Analysis of Cancer Incidence in the Deerfield River Valley

A temporal analysis of each of the cancer types revealed that during the earlier time period (1982-1986), most cancers occurred at or below expected rates, and no significant elevations were observed for any cancer type. During the later time period (1987-1992), the majority of cancers also occurred at or below expected rates. Elevations were observed in female breast cancer (71 observed/66.5 expected; SIR=106) and bladder cancer (7 observed/4.3 expected; SIR=163). However, these elevations were not statistically significant. These results are summarized in Table 1B.

During the earlier time period, multiple myeloma cases occurred as expected. However, during the period 1987-1992, elevations in this cancer were observed among males, females, and among males and females combined. The elevation observed among males and females combined was not statistically significant (8 observed/3.7 expected; SIR=216; 95% CI=93-426). Statistical significance could not be assessed for males or females separately because fewer than five cases were observed.

3. Cancer Incidence in Individual DRV Towns

Cancer incidence data were also evaluated for each of the individual 11 towns located in the DRV for the time period 1982-1992 and the two time periods 1982-1986 and 1987-1992. A discussion of these results is provided below. SIRs for each town are presented in Tables 2 through 12.

SIRs were not calculated when the observed number of cases was less than five. In several towns, less than five cases of cancer were observed for all of the cancer types evaluated. Therefore, a statistical evaluation of trends in the cancer incidence ratio was not possible. These towns include Conway, Florida, Hawley, Heath, Monroe, and Rowe. The BEHA staff did, however, evaluate the occurrence of primary site cancers to determine whether unusual patterns were occurring.

Ashfield (Tables 2A & 2B)

Cancer cases in the town of Ashfield occurred equal to or less often than expected during the period 1982-1992. No statistically significant elevations were observed for any of the cancer types evaluated.

During the period 1982-1986, cancer incidence occurred at or below what would have been expected.

During the period 1987-1992, cancer incidence in Ashfield was generally equal to or less than expected. For those cases where the number of observed cases was greater than the expected number of cases, the elevations were based on less than one case.

Buckland (Tables 3A & 3B)

An elevation in pancreatic cancer occurred during the period 1982-1992. This elevation was due to an excess of three cases which occurred among females and was not statistically significant (5 observed/2.0 expected; SIR=246; 95% CI=79-574).

A slight elevation in overall bladder cancer incidence occurred during the period 1982-1992 (6 observed/4.1 expected; SIR=146). This elevation was not statistically significant (95% CI=53--317) and was due to a slight elevation observed during the later period 1987-1992.

Lung cancer occurred less often than expected during the eleven year period 1982-1992, as well as the two time periods 1982-1986 and 1987-1992.

Charlemont (Table 4A & 4B)

Breast cancer occurred more often than expected during the entire time period 1982-1992 (13 observed/8.2 expected; SIR=158; 95% CI = 84--270) as well as the two time periods 1982-1986 and 1987-1992. None of the elevations were statistically significant.

Bladder cancer was slightly elevated among males and females combined during the period 1982-1992 and the earlier time period 1982-1986. The observed elevations were due to an increased incidence among males. These elevations however were based on excesses of less than two cases.

Lung cancer occurred less than expected in each of the three time periods evaluated (7 observed/8.8 expected; SIR=80).

Conway (Table 5A & 5B)

Cancer incidence during the period 1982-1992 occurred about as expected or slightly less frequently. No cases of bladder, leukemia, liver, pancreas or thyroid cancer occurred.

One case of multiple myeloma occurred while 0.5 cases were expected.

Deerfield (Table 6A & 6B)

During the period 1982-1992, cancer incidence in the town of Deerfield was generally equal to or less than what would have been expected.

A slight elevation was observed in bladder cancer among males and females combined during the period 1982-1992 (12 observed/10.4 expected; SIR=115). This elevation was not statistically significant (95% CI=60-202).

During the period 1982-1992, an overall elevation was observed in NHL. This elevation was due to a statistically significant excess in this cancer observed among females (9 observed/3.8 expected; SIR=238; 95% CI=109-452). When evaluated by separate time periods, the elevation observed during the later time period (1987-1992) was nearly significant (6 observed/2.2 expected; SIR=271; 95%CI=99-590).

An elevation in multiple myeloma was observed for males and females combined. This elevation was due to an excess of approximately two cases and is not statistically significant (5 observed/2.2 expected; SIR=230; 95% CI=74-536).

Bladder cancer in males during 1982-1986 was elevated (5 observed/3.6 expected; SIR=138), but occurred less often than expected during 1987-1992.

During 1982-1986, thyroid cancer occurred more often than expected (2 cases observed versus 0.5 expected). The increase was observed among females, was based on a small number of cases, and was not statistically significant. Thyroid cancer occurred about as expected during 1987-1992.

Florida (Table 7A & 7B)

Cancer incidence in Florida occurred less often than expected during 1982-1992. No cases of kidney, leukemia, multiple myeloma, NHL, or pancreatic cancer were observed during the 11-year time period evaluated. Due to the small number of cases, SIRs were not calculated for the town, however, the observed versus expected numbers are provided in Tables 7A and 7B.

Hawley (Table 8A & 8B)

A total of three cancer cases were observed during the period 1982-1992. These included one case each of kidney cancer, leukemia and multiple myeloma. Although the incidence of these cancers occurred more often than expected, the increases were based on an excess of less than one case. Due to the small number of cases, SIRs were not calculated for the town.

Heath (Table 9A & 9B)

Overall, cancer incidence occurred equal to or less than expected during the period 1982-1992. No cases of NHL or cancer of the kidney, liver, or pancreas occurred during the 11-year period. Due to the small number of cases, SIRs were not calculated for the town.

Monroe (Table 10A & 10B)

One breast cancer case and four lung cancer cases were observed in Monroe during the period 1982-1992.

Breast cancer occurred slightly less often than expected. One case was observed where slightly greater than one case was expected.

Lung cancer occurred more often than expected. Four cases were observed where approximately 1.3 cases were expected. All of the cases occurred during 1982-1986. Due to the small number of cases statistical significance could not be determined.

Rowe (Table 11A & 11B)

During the period 1982-1992, the incidence of several types of cancer was elevated in the town of Rowe. However, with the exception of bladder cancer, these elevations were generally based on about one case or less. There were no cases of cancer of the liver, pancreas or thyroid, while breast cancer occurred about as often as expected.

The incidence of bladder cancer was greater than expected overall and among males during the period 1982-1992. Three cases were observed where one case would have been expected.

An elevation in lung cancer was observed for males and females combined during 1982-1992 (5 observed/3.4 expected; SIR=148; 95% CI=48-345). Although an elevation was observed during this time period, the excess was based on less than two cases and is not statistically significant. All of the five cases occurred during the later time period, 1987-1992.

Breast cancer occurred as expected during the 11-year period 1982-1992. Three cases were observed when slightly greater than three cases would have been expected.

Shelburne (Tables 12A & 12B)

Cancer incidence in the town of Shelburne was equal to or less than expected during the 11-year period 1982-1992. Elevations were observed in both breast cancer and lung cancer. These data are summarized in Table 12A.

Breast cancer was nearly significantly elevated among females (28 observed/19.2 expected; SIR=145; 95% CI=96-210), while no cases were observed among males. Elevations in this cancer were also observed during both time periods 1982-1986 and 1987-1992. The incidence of breast cancer during the later time period was nearly significantly elevated (18 observed/11.1 expected; SIR=162; 95% CI=96-256).

Lung cancer was elevated among males and females combined during the entire 11-year period (20 observed/16.5 expected; SIR=121). The elevation was due to excesses observed in both male and female lung cancer incidence and is not statistically significant. Evaluation of the incidence of this cancer during the two smaller time periods revealed that overall lung cancer occurred as often as was expected during the earlier time period 1982-1986, but was elevated among males during this time (6 observed/4.5 expected; SIR=134). Lung cancer was also elevated during the later time period among males, females and males and females combined. However, none of the elevations observed were statistically significant. These data are summarized on Table 12B.

4. Smoking Status

Cigarette smoking is known to be a causal factor in cancers of the lung and bladder, and is strongly suspected in kidney and pancreatic cancers [Schottenfeld and Fraumeni 1996]. Smoking status information collected at the time of diagnosis for individuals residing in the DRV diagnosed with cancers of the lung, bladder, kidney and pancreas was reviewed. The distribution of smoking status among individuals diagnosed with these cancer types in the DRV and in the state is presented in Figures 2A through 2D.

Figure 2A and 2B present the distribution of cases with a known smoking status for each of the four types of cancer evaluated in the DRV and the state. With the exception of pancreatic cancer,

for each of the cancer types evaluated in both the DRV and the state, there were a greater percentage of current and former smokers than individuals who never reported smoking.

Smoking is the primary risk factor for lung cancer. During the period 1982-1992, a total of 95 lung cancer cases were observed in the 11 DRV towns. Of the 95 cases, smoking status was unknown for 13% (n=12) of the individuals. Among the individuals diagnosed with lung cancer for which smoking status was known (n=83), 95% (n=79) were current or former smokers and 5% (n=4) had never smoked. The distribution of smoking status among individuals diagnosed with lung cancer in the DRV was consistent with the distribution among lung cancer cases in the state (refer to Figures 2C and 2D). Bladder cancer is strongly associated with a history of cigarette smoking. There were 33 bladder cancer cases observed in the 11 DRV towns. Smoking status at the time of diagnosis was unknown for 15% (n=5) of these individuals. Among those individuals for which smoking status was known (n=28), 64% (n=18) were current or former smokers and 36% (n=10) had never smoked. The distribution of smoking status among individuals diagnosed with bladder cancer in the DRV was also consistent with the distribution among bladder cancer cases in the state.

Although many risk factors have been suggested for kidney cancer, cigarette smoking remains one of the most important risk factors for the disease. Fourteen kidney cancer cases were observed in the DRV area. Of the 14 cases, smoking status was unknown for two cases. Seven of the 12 cases were current or former smokers and five had never smoked. The distribution of smoking status among individuals diagnosed with kidney cancer in the DRV was consistent with the distribution among kidney cancer cases in the state.

Information on smoking status was available for 10 of 13 pancreatic cancer cases observed in the DRV. Of these 10 cases, three were current or former smokers and seven had never smoked. Smoking has also been identified as a possible risk factor in the development of the leukemia subtype, acute myelocytic leukemia (AML), and has been weakly associated with another leukemia subtype, chronic myelocytic leukemia (CML) [Sandler 1993, Wald 1980]. Fourteen leukemia cases were diagnosed in the 11 DRV towns during 1982-1992. Of these cases, there were four AML cases and one CML case. For these five leukemia cases, three were current or former smokers, one case reported never smoking, and the smoking status of the remaining case was unknown.

Smoking status at the time of diagnosis was also evaluated in the towns that experienced an elevation in cancers of the lung, bladder, kidney, or pancreas. Many towns did not experience elevations in these cancer types, and were not evaluated. Review of smoking status in individual towns showed that the distribution of current or former smokers was similar to that observed for these cancer types in the DRV towns combined.

In Buckland, six bladder cancer cases were observed in 1982-1992. Of the six cases, two had never smoked, three were current or former smokers, and the status of the remaining case could not be determined. Five pancreatic cancer cases were observed in Buckland during 1982-1992. Of the five cases, two had never smoked, two were current smokers, and the status of one case was unknown.

In Charlemont, four bladder cancer cases were observed during 1982-1992. At the time of diagnosis, all four of the cases were current or former smokers.

In Deerfield, 12 bladder cancer cases were observed in during 1982-1992. Of the 12 cases, three had never smoked, six were current or former smokers, and the status of the remaining three could not be determined.

In Monroe, four lung cancer cases were observed during 1982-1992. All four of the cases were current or former smokers.

In Rowe, five lung cancer cases were observed during 1982-1992. All five of the cases were current or former smokers. Three bladder cancer cases were observed during 1982-1992. All three of the cases had never smoked.

In Shelburne, 20 lung cancer cases were observed during 1982-1992. Of the twenty cases, two had never smoked, fourteen were current or former smokers, and the status of the remaining four could not be determined.

5. Occupation

Several types of cancer have been associated with occupational exposures in certain industries, including cancers of the bladder, kidney, liver, lung, and pancreas, as well as leukemia, multiple myeloma, and NHL [Shottenfeld and Fraumeni 1996, Higginson 1992]. Occupational information reported at the time of diagnosis was reviewed for individuals diagnosed with these types of cancer.

Three bladder cancer cases reported occupations that have been associated with an increased risk of developing the disease. One lung cancer case reported exposure to asbestos, a known causal agent in the development of that disease. Fourteen lung cancer cases reported occupations in which exposures associated with lung cancer were possible. One pancreatic cancer case also reported an occupation in which industrial exposures suspected in the development of that cancer would be possible.

Occupational status was also examined for female NHL cases in the town of Deerfield. A significant elevation of this cancer was observed among females during 1982-1992. Of the nine female cases reported, two cases reported occupations at the time of diagnosis in which exposures associated with NHL were possible.

The incidence of multiple myeloma was elevated although not significantly in the DRV towns combined. Review of occupational information for these individuals revealed that none of the cases reported an occupation in which exposures are known or suspected to be associated with this disease. Other than the above information, no specific exposures or occupations associated with cancer were reported by individual cases in the DRV.

Occupational information was limited to "unknown", "at home", or "retired" for approximately 31% (n=99) of the cancer cases in the DRV. Generally, the available information was not sufficient to determine whether occupational exposures may have occurred in some cases or what role occupation may have had in cancer incidence in the region.

6. Geographic Distribution

The geographic distribution of cancer cases in the DRV area was evaluated with respect to each of the cases' proximity to the Deerfield River. In general, most cases did not reside alongside the Deerfield River (i.e., within 0.25 miles) and there did not appear to be any unusual patterns of incidence along the river for any of the cancer types evaluated.

In some towns, such as Buckland and Shelburne, the majority of cases resided in certain areas of the towns. However, these areas were also the most densely populated and hence would be expected to have a greater concentration of cases. In the town of Charlemont, where more cases

resided in the river vicinity, the distribution of cases was consistent with what would be expected given the variation in population density throughout the town.

Although the incidence of NHL was significantly elevated among females in Deerfield (9 cases observed versus 3.8 cases expected), no apparent clustering of cases was observed during any of the time periods evaluated. Residence at the time of diagnosis was greater than one mile from the river for five of the cases. One case resided slightly less than one mile from the river. And the remaining three cases resided within one-half mile of the river.

In addition, the incidence of breast cancer was nearly significantly elevated in the town of Shelburne. Although the incidence of this cancer appeared to increase during the later time period 1987-1992, the geographic distribution of cases was evenly distributed throughout the town. The majority of the cases resided in the downtown area where the population density is greater than in other areas of town. Through the Massachusetts Breast Cancer Initiative this issue is being more thoroughly investigated.

For multiple myeloma, residence at the time of diagnosis was greater than one mile from the river for all cases mapped (i.e., 10 of the 11 cases). The cases were also evenly distributed throughout the 11 towns of the DRV.

Thyroid cancer was also slightly elevated during 1982-1992 for the DRV towns combined. Residence at the time of diagnosis was greater than one mile from the river for five of the seven cases and one case resided within half a mile of the river. The remaining case could not be mapped due to inadequate address information.

For lung cancer in Monroe, which was slightly elevated during 1982-1992, residence at the time of diagnosis was within half a mile from the river for three of the four cases. The remaining case resided approximately one mile from the river.

Among lung cancer cases in the town of Rowe, residence at the time of diagnosis was greater than one mile from the river for all five cases. Six lung cancer cases in the town of Shelburne were also located greater than one mile from the river. One case resided slightly less than one mile from the river. The remaining eleven cases resided within one half mile of the river. One case could not be mapped due to inadequate address information.

The geographic distribution of cases was also evaluated based on boundaries of the DRV as defined by the CAN [CAN 1996] (refer to Figure 1B). The CAN boundary is geographically smaller than the 11 town study area and excludes most of the towns of Deerfield and Heath and portions of the remaining towns. Since the boundary is smaller, a number of cancer cases are excluded, especially in South Deerfield and the town of Ashfield. A total of 159 cases (approximately 57% of the mapped cases) were located outside of the CAN boundary.

Review of cancer cases in relation to this defined area revealed that no geographic concentrations or clustering of cases occurred. For multiple myeloma, (which was slightly elevated during 1982-1992 for the DRV towns combined), eight of the ten cases were located outside the CAN boundary.

In order to evaluate the geographic distribution of cancer cases, considerable effort was expended to locate each case as to the exact residence at the time of diagnosis. Despite this effort, the location of 46 cases (approximately 14%) was not able to be determined. Although these cases were not mapped due to insufficient address information, SIRs were calculated based on the total number of cases observed for each cancer type in the 11 DRV towns. The following cases could not be geographically located due to insufficient information regarding an exact residence:

In Ashfield, one breast cancer case, two lung cancer cases and one leukemia case;

In Charlemont, three breast cancer cases, three bladder cancer cases, and one NHL;

In Conway, one lung cancer case;

In Deerfield, four breast cancer cases, one bladder cancer case, four lung cancer cases, one case of multiple myeloma, NHL and thyroid cancer and two cases of pancreatic cancer;

In Florida, one breast cancer case;

In Monroe, one breast cancer case;

In Rowe, one case each of breast cancer, lung cancer and kidney cancer;

In Shelburne, ten breast cancer cases, two bladder cancer cases, one leukemia case and one case of lung cancer.

B. Down Syndrome Prevalence Analysis

1. Case Description

For the purposes of this investigation a DS case was defined as an infant who: (a) was a live birth and not a stillbirth, spontaneous abortion, or medical abortion; (b) was born during the time period 1980 through 1990; (c) had a mother with a verifiable residence in the DRV at the time of birth, and; (d) had a confirmed diagnosis of DS from one of the following sources: chromosome analysis, medical record indicators, vital records, outreach programs, and CAN reported cases.

The CAN reported a total of 21 children as having DS in the DRV area. Of the 21 children reported, 13 were excluded from further evaluation because they did not meet the established case definition. Of these 13 children, three were excluded because they were not a live birth. The date of birth was unknown for two children. Six children were born prior to 1980 and the residence at birth for two children was outside the 11 DRV towns evaluated. Therefore, eight children met the established case definition for inclusion in this evaluation and the diagnosis of DS was confirmed for these eight children. The resolution of reported DS cases is provided in Figure 3.

The maternal age range at the time of birth for the eight confirmed DS cases was between 20 and 40 years old. Five of the mothers were between the ages of 30 to 34 years old. Only one mother was older than age 35 at the time of birth. Of the remaining mothers, one was in her early 20s and one was in her late 20s.

2. Geographic and Temporal Distribution

Residence at birth was mapped for the eight confirmed DS cases included in the analysis. Due to confidentiality, the maps are not displayed in this report.

The geographic distribution of the cases according to residence at birth revealed that three of the eight cases occurred in Buckland, two in Shelburne, and three occurred individually in separate towns.

The median distance of the eight cases from the Yankee Rowe plant was approximately 12.5 miles, with a range of 10 to 21 miles. The three Buckland cases were located approximately two miles from the Deerfield River. In addition, the Buckland cases occurred in close proximity to each other (i.e., less than 0.25 miles). The remaining five cases varied in their proximity to the Deerfield River from less than 0.25 miles to as much as three miles. With the exception of the three cases in Buckland, there was no apparent geographic pattern of DS cases in relation to each other or the Deerfield River.

Evaluation of the temporal distribution of cases showed that the three Buckland cases occurred in 1985, 1986, and 1990. Of the remaining cases that occurred in other towns, three cases occurred in 1982, one case in 1985, and one case in 1989. Three cases occurred in a short temporal period (1982), however, each of these cases occurred in a different town.

Five cases exhibited some seasonality, occurring during the months of May through August, while the other three cases occurred during March, October, and December. Although, three cases occurred in 1982, each of these cases occurred in a different quarter of the year. The temporal distribution of DS cases is provided in Table 13 and Figure 4.

3. Prevalence

During the period 1980-1990, there were a total of 2,187 live births in the 11 DRV towns. Thus, the crude prevalence of DS during 1980-1990 in the 11 DRV towns combined is 8 cases per 2,187 live births or 3.66 cases per 1,000 live births. When calculated separately for the five towns in which a DS case occurred, the crude prevalence of DS for these five towns was 8 cases per 1,653 live births or 4.84 cases per 1,000 live births (Table 14).

The number of DS cases that would have been expected to occur during the period 1980-1990 was calculated based on the prevalence of DS observed in the state of California during 1983-1986 [CBDMP 1990]. If the 11 DRV towns had experienced a prevalence of DS similar to the prevalence observed in California, 2.46 DS births would have been expected to occur during the period 1980-1990. The ratio of observed to expected cases adjusted for maternal age at birth was 3.25. The 95% confidence limits ranged from 1.40 to 6.41, indicating that the ratio of observed to expected DS cases in the 11 DRV towns was statistically significant (Refer to Table 15).

Similarly, for the five DRV towns in which DS cases were born, 1.85 (age-adjusted) DS births would have been expected. The ratio of observed to expected cases was 4.32. The range of the confidence interval (95% CI = [1.86-8.52]) indicates that the prevalence of DS in the five towns for the period 1980-1990 was also statistically significantly increased (Refer to Table 16).

C. Environmental Data

1. Radionuclides Sampling

In December 1992, the MDPH Radiation Control Program collected drinking water samples from six residences located in the towns of Charlemont and Buckland. The locations of these samples ranged in distance from within 0.25 to approximately 2 miles from the Deerfield River. The sampling and locations were conducted at the request of the CAN. The samples were analyzed by the Massachusetts Environmental Radiation Laboratory for the presence of gross alpha, gross beta and gamma radionuclides as well as for the presence of tritium via liquid scintillation. The results of the sampling were evaluated based on the known instrument detection limits and compared to regulatory limits established by the United States Environmental Protection Agency (USEPA) and the Nuclear Regulatory Commission (NRC) [MDPH 1993].

Results of the analyses showed that all of the samples were below the established regulatory limits. None of the samples detected a positive result for the presence of gamma, gross alpha, or tritium. Three of the samples were positive for gross beta radionuclides. One of these samples detected the presence of gross beta radionuclides above the minimum detection limit of 3 pCi/L, but below the regulatory limits [MDPH 1993].

2. Tritium Exposures

In 1993, an assessment was conducted of potential exposures to DRV residents from tritium (^3H) released from the Yankee Rowe plant [MacIntosh et al. 1993]. The authors developed a model that assumed a 30-year exposure period, intended to represent historical exposures during the operational life of Yankee Rowe, from 1961-1992. Tritium concentrations and the dose to DRV residents were estimated based on meteorologic data for the area and average annual concentrations of ^3H released from Yankee Rowe. The exposure conditions included inhalation, ingestion, and dermal absorption as a result of tritium present in water in the Deerfield River and evaporation of water from the Deerfield River into the ambient air.

Based on these assumptions, the estimated annual tritium dose to individuals in the DRV was 0.33 milli-rems (mrem) (radiation equivalent man) and the 30-year exposure dose was 9.82 mrems. For comparison, the annual natural background radiation received by humans is approximately 350 mrems. The authors then estimated potential health effects associated with the calculated annual and 30-year cumulative ^3H doses by comparing these doses to dose-response models developed by the Nuclear Regulatory Commission [MacIntosh et al 1993]. The results indicated that it is unlikely that tritium exposures to DRV residents would result in an increased incidence of brain cancer, breast cancer, leukemia, or DS [MacIntosh et al. 1993]. In addition, based on this assessment, the authors made four conclusions. "First, ^3H concentrations in the DRV environmental media during the operational phase of the Yankee Rowe facility may have been several orders of magnitude greater than those in typical unimpacted areas. Second, assuming that few DRV residents obtain their water from the Deerfield River, the dominant source of ^3H exposure is inhalation and dermal absorption of airborne HTO (assuming ^3H is a component of water molecules) as a result of its evaporation from the river. Third, ^3H exposures from intermittent gaseous releases from Yankee Rowe were probably insignificant compared to river related exposures. And finally, ^3H doses resulting from Yankee Rowe operations and delivered as HTO were probably several orders of magnitude lower than those from all natural sources of radiation."

In 1994, the NRC estimated the dose of tritium to the DRV population based on reported releases by Yankee Rowe during the years 1966-1972 [Willis 1994]. Their calculations were based on estimated population doses resulting from liquid effluent discharged from nuclear power plants in 1989. The calculation was then adapted to account for the approximately 10,000 curies of tritium discharged as liquid effluent and the approximately 58 curies released to the air during 1966-1972. The results estimated that the tritium dose to the 1989 population in the DRV based on the aforementioned amounts would be 1 person-rem (this is a population dose). This would be equivalent to an annual dose of 0.04 mrems per person.

3. 21E and TRI Sites

The most recent information on 21E sites located in the 11 DRV towns and listed by the Massachusetts Department of Environmental Protection (MDEP) was obtained and reviewed. The MDEP is responsible for the monitoring, assessment and clean-up of releases of oil and hazardous materials at disposal sites (subsequently named 21E sites) in Massachusetts. These sites are regulated under Massachusetts General Laws, Chapter 21E. Facilities located in the DRV and listed by the USEPA in the Toxics Release Inventory (TRI) were also reviewed. The TRI

contains information on the type and amount of chemicals stored on-site or released to the environment by companies and manufacturers.

A total of ten sites located in the 11 DRV towns were identified by the MDEP as Confirmed Disposal Sites or Locations to be Investigated during 1987-1993 [MDEP 1995]. The status of three of these sites was subsequently modified to indicate that the location was not a disposal site or did not currently require further remedial response actions. The remaining seven sites were located in the towns of Charlemont, Conway, Deerfield, and Buckland. None of the seven sites were on the USEPA National Priority List of the most serious uncontrolled or abandoned hazardous waste sites.

Four TRI facilities were identified in the DRV area during the period 1988-1991 [USEPA 1994]. These four facilities were located in South Deerfield. Evaluation of the geographic distribution of cancer and DS cases in relation to these sites revealed no apparent clustering or geographic concentration of cases. Refer to Figure 5 for the location of MDEP 21E sites and TRI sites.

VI. DISCUSSION

A. Cancer

The available data do not suggest that residents of the DRV experienced excessive rates of cancer incidence during the period 1982-1992. For most primary sites, cancer cases occurred at or below expected rates in the 11 DRV towns as a whole and in each of the towns individually. Among females however, statistically significant and nearly significant elevations occurred in NHL in the town of Deerfield and breast cancer in the town of Shelburne. A non-significant elevation in multiple myeloma incidence was noted in the DRV overall.

NHL was significantly elevated among women in the town of Deerfield during the entire 11-year period 1982-1992. The majority of cases occurred during 1987-1992. The geographic distribution of NHL incidence in Deerfield did not reveal any unusual concentration of cases. Although two of the cases reported an occupation in which exposures associated with NHL were possible, occupational information reported at the time of diagnosis was too limited to determine whether or not exposures associated with the development of NHL may have occurred in some cases. For this reason it may be important to further evaluate the cases of NHL in Deerfield.

Although a nearly significant elevation was observed in breast cancer among females in the town of Shelburne, no geographic pattern or unusual concentration of cases was observed in the town during any of the time periods evaluated. However, the incidence of breast cancer appears to have increased over time in this town, and was more pronounced in the later time period. As previously noted, MDPH is further evaluating the incidence of breast cancer incidence in the town of Shelburne through the Massachusetts Breast Cancer Initiative.

Elevations were observed in the incidence of multiple myeloma in the DRV towns combined. The elevations were not statistically significant during 1982-1992, however this cancer was consistently elevated among both males and females. In addition, the cases were widely spread throughout the region and occupational information was not detailed enough to evaluate whether any cases experienced exposures that might have contributed to the development of their cancers. However, this type of cancer is relatively rare and the only known risk factor is exposure to ionizing radiation.

No unusual geographic patterns of cancer incidence were apparent that would suggest that a common environmental factor may have played a role in the development of these cancers. Furthermore, the distribution of cases in relation to the Deerfield River did not reveal a pattern

that would suggest an association between any of the cancer types evaluated and proximity to the river. No apparent clustering or concentration of cases was observed in relation to 21E sites or TRI sites. When the distribution of cancer cases were evaluated in relation the boundaries of the DRV defined by the CAN, the majority of cases were located outside of the defined boundaries. Moreover, there was no apparent geographic pattern of any one cancer type or within any individual town located within the confines of the CAN boundary.

B. Down syndrome

Despite intensive research over the last two decades, the causes of DS remain essentially unknown. However, the epidemiology and prevalence of DS are well characterized and some risk factors (i.e., maternal age) are well established and can be described in relation to the DRV cases.

It is believed that DS occurs at or around conception [Behrman, et al. 1992]. In the usual case of DS, either the egg or the sperm cell contributed 24 chromosomes, instead of 23. The result is that the child carries 47 chromosomes, instead of the normal 46. The extra chromosome donated by the mother or father is usually chromosome #21; so that the child has three copies of chromosome #21. Because of the presence of three #21 chromosomes, DS is also referred to as trisomy-21.

The extra chromosome results in a combination of birth defects including mental retardation and characteristic facial features. Other common health problems associated with DS are congenital heart defects, visual and hearing impairment, and intestinal malformations. DS children are also at increased risk for thyroid problems, leukemia, bronchitis and pneumonia [March of Dimes 1996].

In the DRV during 1980-1990, eight cases of DS met the case definition established for this evaluation. Based on these eight cases, the prevalence in the DRV was approximately 4 cases per 1,000 live births. While some variation exists between ethnic groups and cultures, the crude prevalence (not age-adjusted) of DS in the United States is approximately one case per 1,000 live births [CBDMP 1990, Claude, et al 1990, Janerich and Bracken 1986, March of Dimes 1996, MMWR 1994]. Hence, the DRV prevalence is approximately four times higher than the reported crude prevalence of one case per 1,000 live births observed among the U.S. population.

Based on the prevalence of DS in California, approximately two cases would have been expected in the DRV based on the number of live births that occurred in this area during 1980-1990. The ratio of observed to expected cases was 3.25, and the 95% confidence interval was statistically significant (95% CI=1.41-6.41).

The prevalence of DS in the DRV was also greater than expected when compared to historical estimates of DS prevalence in Massachusetts [Rothman and Fabia 1976]. According to Rothman and Fabia, the prevalence estimate for Massachusetts during 1950-1966 was 1.35 cases per 1,000 live births. The prevalence estimates for Franklin county during the same time period was 1.06 cases per 1,000 live births. In this study active case ascertainment was used to discover 2,774 children with DS in Massachusetts born between 1950 and 1966. The results were compiled by county as well as for the state. An analysis for space and time clustering of the births of 2,469 children born with DS revealed no aggregation of cases in Massachusetts or any of its counties, including Franklin and Berkshire counties. This is important because the time period of study includes at least part of Yankee Rowe's operational history. In addition, the period 1961-1966 is when radiation releases to the environment by Yankee Rowe were likely to be larger than the 1970s and 1980s, and yet there was no detectable increase in DS children during the earlier time period. However, comparison to these data should be cautious because the secular trends of DS and the distribution of maternal age in this study are unknown. In addition, other factors

such as improved prenatal screening and cytogenetic testing make historical comparisons less valid.

The study conducted by Rothman and Fabia detected a slight seasonal peak of DS births during the summer. The DS cases in the DRV displayed a similar seasonal peak, with five of the eight cases occurring between May and August. However, the DRV data were not standardized to account for variations in monthly births. Increases in all births in the DRV during May through August could partially explain the seasonal tendency of the DS cases. Although seasonal variation has been detected by other investigators [Harlap 1974, Jongbloet and Vrieze 1985, Singh, et al 1995, Troya, et al 1985, Videbech and Nielsen 1984], no consensus has been reached as to the cause of this variation.

There are a number of possibilities and risk factors that could contribute to the elevated prevalence of DS in the DRV, including chance, but according to the 95% confidence interval the likelihood of this number of cases occurring by chance alone is less than five percent. Advanced maternal age is the most well documented risk factor associated with DS. Age-specific prevalence reveals the substantial variation in age and risk of a DS child. The prevalence of DS ranges from approximately 0.8 case per 1,000 live births for 25-year olds to approximately 9.4 cases per 1,000 live births at age 40 [March of Dimes 1996].

The maternal age range of the eight confirmed cases was between 20 and 40 years old at the time of birth. However, only one of the mothers was older than age 35. When the expected prevalence of DS in the DRV was adjusted using California age-specific prevalence, the expected number of cases in the DRV increased from 2.21 to 2.46. Thus, maternal age was not a significant confounder of the comparison between the 11 DRV towns and California.

Two factors may influence the maternal age-specific prevalence of DS. First, the age distribution of mothers having DS children is influenced by the fact that younger women tend to have more children than relatively older women. As a result, most (i.e., 70 percent) DS children are born to women under the age of 35 [March of Dimes 1996, Janerich and Bracken 1986, Dellarco et al. 1985]. In addition, women over the age of 35 are more likely to receive pre-natal screening (i.e., amniocentesis) for the determination of a trisomic fetus. It is estimated that approximately 90% of women who test positive for a trisomic fetus will chose to terminate their pregnancy; further lowering the prevalence of DS children born to mothers over age 35 [Edmonds 1996, Vincent 1991].

Another risk factor associated with DS is a sibling with Down syndrome. In this case, the chance of having another child with DS is approximately 1 percent in each subsequent pregnancy [March of Dimes 1996]. However, if the first child has translocation DS, the chance of having another child with DS is greatly increased (to about 10 percent) [Behrman et al. 1992]. Translocation DS is believed to be a relatively more fixed genetic condition in the mother or father, resulting in a much higher risk for DS children that is independent of maternal age.

Thus far, the only well established factors associated the prevalence of DS among live births are maternal age, other siblings with DS, and prenatal screening. However, a number of studies have also suggested associations between external factors and Down syndrome. These associations, which are generally weak and not reproducible, include but are not limited to advanced paternal age, birth order, viral and other microbial agents, and exposure to a number of drugs or chemicals (i.e., medications, tobacco smoke, pesticides) [Janerich and Bracken 1986]. Exposure to low-level ionizing radiation among mothers has also been indicated as an external factor associated with DS. However, the association between DS and low-level radiation suggested in epidemiological studies remains unclear [BEIR V 1990].

1. Studies of Radiation Exposures and Down Syndrome

At least thirteen studies in various countries have examined the possible role of radiation exposures from medical treatments (e.g., x-rays) in the mothers of DS children. Four studies have shown a statistically significant positive association between maternal radiation exposure before conception and the birth of a DS child. Of the remaining nine studies in which no statistical significance was attained, five were in the positive direction, two showed no difference, and two were in the negative direction [BEIR V 1990].

The question of whether the occurrence of birth defects has increased due to radioactive fallout from weapons testing, accidents at nuclear power plants and normal emissions from nuclear power plants has been addressed in many studies. In several of these studies, special interest was given to DS as an indicator condition of chromosomal anomalies.

A recent study in England concluded that population exposure to fallout originating from atmospheric nuclear weapons testing may play some part in the cause of DS, particularly for mothers of older age groups [Bound et al. 1995]. The size and the frequency of the dose mattered less than the accumulated total of radiation received. The authors assert that their results provide further evidence of low dose ionizing radiation as an etiologic factor in Down syndrome.

Sperling et al., examined a significant increase in children with DS in Berlin nine months after the Chernobyl reactor accident [Sperling et al. 1994]. The authors concluded that the significant increase in the prevalence of DS in West Berlin was causally related to a short period of exposure to ionizing radiation released during the Chernobyl reactor accident [Sperling et al. 1994]. The authors of a similar study found a significant increase in DS prevalence in Scotland for two years after the Chernobyl accident. However, the authors concluded that because the study area (Scotland) had very low levels of radioactive fallout, it was unlikely that fallout from the accident could be causally linked to the increased prevalence of DS [Ramsay, et al. 1991].

In Finland, a detailed comparison was made of the distribution of DS children according to levels of radioactive fallout from the Chernobyl accident [Harjulehto-Mervaala et al. 1992]. The study was based on 518 cytogenetically verified cases of DS born during 1984-1988. Children conceived before the accident were compared with children conceived after the accident. The children were also divided into three subgroups according to radiation zones delineating the amounts of radioactive fallout. The results indicated that there were no significant differences in the prevalence of DS between children conceived before and after the accident. There were also no differences between the three case subgroups despite the significant differences in levels of radiation in each zone.

The rates of birth defects, stillbirths, and infant deaths among children of residents of communities in close proximity to the Pickering Nuclear Generating Station in Ontario, Canada has also been investigated [Johnson and Jocelyn 1991]. This study investigated whether an association existed between monthly airborne or waterborne tritium emissions from the power plant and the rates of these reproductive outcomes. The results did not support the hypothesis of increased rates of stillbirths, neonatal mortality, or infant mortality in the vicinity of the Pickering power plant. The analysis also did not support a hypothesis of increased rates of birth defects in 21 of the 22 diagnostic categories studied [Johnson and Joceylyn 1991]. The authors did find that the prevalence of DS births was statistically significantly elevated. However, the analysis provided no consistent pattern between tritium releases or groundwater monitoring data and the prevalence of Down syndrome. The authors recommended further study to determine whether a relationship exists between the tritium releases and increased DS prevalence in this area [Johnson and Jocelyn 1991].

In summary, despite decades of intensive research the causes of DS remain essentially unknown. Certain factors affecting the prevalence have been clearly delineated, such as, maternal age, previous siblings with DS, and pre-natal screening. Although a number of studies have been conducted to explore the relationship between DS and ionizing radiation, a relationship between the two has not been clearly established.

Of particular interest to the CAN and local citizens were not only the apparently high prevalence of DS in the DRV, but the possible relationship to periodic radioactive releases (i.e., tritium) from Yankee Rowe. While it is possible that some relationship may exist between radioactive releases from Yankee Rowe and the increase in DS prevalence, there are several pieces of evidence that might suggest that this relationship is not likely.

Although relatively large doses of ionizing radiation (i.e., 100 to 600 rems) have been shown more clearly to cause non-disjunction in mice, its ability to do so in humans remains unclear [BEIR V]. In addition, no association has been established between DS and tritium [NCRP Report no. 63, 1979].

Second, water sampling and analysis conducted in Charlemont and Buckland during 1992 (nearest to Yankee Rowe of the DS towns) did not detect the presence of gamma, gross alpha, or tritium. In addition, no information is available regarding the exposure of DRV individuals or parents with DS children and exposure to ionizing radiation. However, there are limited data documenting DRV residents past and present potential exposure to environmental agents.

Two reports discuss or model potential exposure of DRV residents to radiation products generated by Yankee Rowe [MacIntosh et al. 1993, Willis 1994]. Both models estimated similar individual (and population) doses of tritium, and consequently, both models reached similar conclusions. The study by MacIntosh et al indicated that it was unlikely that exposure to HTO via routine releases from Yankee Rowe would result in an increased incidence of DS among DRV residents [MacIntosh et al. 1993]. Willis concluded that tritium releases did not significantly increase the radiation exposure in the DRV and are therefore not related to the reported health effects in the DRV.

Further, the median distance of the eight cases to Yankee Rowe was 12.5 miles with a range of 10 to 21 miles. Without strong evidence indicating a cause and effect relationship between ionizing radiation and DS, it is unlikely that routine radioactive releases from Yankee Rowe could cause non-disjunction over such a wide range of distance.

In addition, although the prevalence of DS is elevated, the eight cases occurred in an area of approximately 110 square miles. Three cases are grouped in relatively close proximity (less than 0.25 miles) in Buckland, yet these cases occurred over a period of five years. Three other cases also occurred in 1982, yet each case occurred in a different town. These results are primarily descriptive and must be interpreted with caution. Therefore, the MDPH will recommend further study of the families and children with DS.

VII. LIMITATIONS

This investigation is descriptive in nature and can only provide a comparison of the incidence of cancer and Down syndrome prevalence in the DRV to the incidence of cancer and Down syndrome prevalence in the state of Massachusetts or other larger and more stable populations. Only routinely collected data are analyzed and information about personal risk factors (e.g., genetics, smoking, diet, family history), which may influence cancer incidence and possibly DS, is often limited and is not of an historical nature. It is beyond the scope of this investigation to determine any causal relationship or synergistic roles that the risk factors discussed in this report may have played in the development of cancer and DS in the DRV.

This investigation is also limited by the relatively small number of cases and hence the instability of the calculated rates. For many of the specific cancer types in the DRV towns a small number of cases occurred. Therefore, evaluation of the incidence of these cancers over time was difficult and SIRs could not be calculated for these cancers in a number of towns. In addition, a change in only one or two cases could result in a large change in the estimated prevalence or incidence rate for the DRV. In relatively small towns such as these, rates will fluctuate over time ranging from no cases to a "statistically significant" excess of cases.

Furthermore, the lack of a congenital anomalies database has precluded the ability to determine an accurate prevalence of Down syndrome in the DRV.

VIII. CONCLUSIONS

General Conclusions:

The available data do not suggest that residents of the DRV experienced excessive rates of cancer during the period 1982-1992. For the majority of cancer types evaluated, cancer cases occurred at the same rate or a lower rate than would have been expected based on statewide cancer incidence. No unusual temporal or geographic patterns were observed in any of the 11 towns evaluated, which would suggest an environmental factor is related to the incidence of cancer in this area.

No unusual geographic pattern of cancer incidence was observed with respect to proximity to the Deerfield River for any of the 10 cancer types evaluated. The majority of cases were located greater than one mile from the river at the time of diagnosis. No apparent clustering or concentration of cases was observed in relation to 21E sites or TRI sites. Moreover, there was no apparent geographic pattern of any one cancer type or within any individual town located within the confines of the CAN boundary.

Based on comparisons with national data, the prevalence of Down Syndrome in the DRV during the period 1980-1990 was elevated. This elevation is based upon eight confirmed cases. The prevalence of DS was significantly elevated when compared to the prevalence reported in California.

Specific Conclusions:

A statistically significant elevation was observed for NHL among females in the town of Deerfield. A nearly statistically significant elevation in breast cancer incidence was observed among females in the town of Shelburne. In addition, non-significant elevations in multiple myeloma incidence were noted in the DRV overall.

Although NHL was significantly elevated among women in Deerfield during 1982-1992, the elevation was based on approximately five excess cases. Most of the elevation occurred during 1987-1992 and the number of excess cases is relatively small. The geographic distribution of NHL incidence in Deerfield did not reveal any unusual concentration of cases. Occupational information reported at the time of diagnosis revealed two cases reported an occupation that is associated with an increased risk for this disease. However, occupational information was too limited for the remaining cases to determine whether or not exposures associated with the development of NHL may have occurred in the remaining cases.

An elevation was observed in breast cancer among females in the town of Shelburne. Although this elevation was nearly statistically significant, no geographic pattern or

concentration of cases was observed in the town during any of the time periods evaluated. However, the incidence of this cancer appears to have increased over time in Shelburne and was more pronounced during the later time period 1987-1992.

Elevations in multiple myeloma incidence in the DRV were not statistically significant during 1982-1992, and the cases were widely spread throughout the region. Although the current data do not suggest that a common factor is likely in the development of these cases, the occupational information for these individuals was not detailed enough to evaluate whether cases experienced exposures, which contributed to the development of their cancers.

A spatial cluster of 3 children with DS occurred in Buckland during the 1980s. However, evaluation of the time frame of birth for all 8 children did not indicate an unusual pattern (e.g., a temporal cluster).

Although some epidemiologic studies have associated the occurrence of DS with exposure to ionizing radiation, the association is still debated. In addition, exposure to tritium has not been found to be associated with the occurrence of Down Syndrome. Evaluations of the potential exposure of DRV residents to tritium present in the Deerfield River concluded that the estimated dose of tritium received from the Deerfield River as a result of operations from the Yankee Rowe nuclear power station was several orders of magnitude lower than the dose received from all natural sources of radiation.

The environment (i.e. exposure to tritium) has not been ruled out as a potential factor in the development of cancer and birth defects in residents of the DRV. However, based on health risk assessments conducted by other researchers and the available data reviewed in this report, it seems unlikely that tritium exposures to DRV residents would have resulted in an increase in the occurrence of cancer or Down Syndrome.

IX. RECOMMENDATIONS

Due to the significant elevation observed in the incidence of non-Hodgkin's lymphoma among females in Deerfield, the MDPH will further evaluate the residential and occupational histories of these cases (Appendix B).

Although elevations in multiple myeloma incidence were observed in the 11 DRV towns combined, an analysis of the geographic distribution of these cases did not suggest that a common factor is likely in the development of these cases. However, this type of cancer is relatively rare and the only known risk factor is exposure to ionizing radiation. The occupational information for these individuals was not detailed enough to evaluate whether cases experienced exposures that contributed to the development of their cancers. Therefore, the MDPH will further evaluate occupational histories for multiple myeloma cases in the DRV (Appendix B).

The CAU is currently conducting an in-depth analysis of breast cancer incidence in the town of Shelburne. This analysis will include further evaluation of the age distribution of cases; temporal and spatial trends over the time period 1982-1992; and the distribution of stage of breast cancer among cases in this town. In addition, the BEHA is presently involved in a research initiative exploring a potential relationship between breast cancer and environmental agents, including polychlorinated biphenyls (PCBs) and pesticides in Western Massachusetts (Appendix C).

Although the prevalence of DS in the DRV was elevated, no unusual geographic pattern was observed among these children in relation to the environmental data reviewed that seems to explain the occurrence of DS in the DRV. Maternal age did not appear to explain the increased prevalence of DS. A seasonal pattern was observed among these cases. After discussion with the U.S. Centers for Disease Control (CDC), the MDPH recommends that the conduct of further investigations of potential individual factors that may be related to the occurrence of DS among these children be discussed with the families of children with DS, the CDC, and the CAN. Should these groups determine that follow-up investigations would lead to a better understanding of DS among these children, the MDPH recommends that such additional investigation be conducted in cooperation with the Centers for Disease Control, National Center for Environmental Health.

The MDPH/BEHA will continue to monitor cancer incidence rates in the 11 DRV towns through the Massachusetts Cancer Registry.

X. REFERENCES

Adlercreutz, H. Western diet and Western diseases: some hormonal and biochemical mechanisms and associations. *Scand J Clin Lab Invest, Suppl.* 1990; 201: 3-23.

Alberman, et al. Parental exposure to X-irradiation and Down's syndrome. *Annals of Human Genetics.* 1972; 36: 195-208.

Amdur, M., J. Doull, and C. Klaassen. Casarett and Doull's Toxicology: The Basic Science of Poisons. 4th Edition. (New York: McGraw-Hill, Inc., 1991). pp. 985-997.

American Cancer Society. *Cancer Facts & Figures* 1995. Atlanta, Georgia.

Antonarakis, S. Parental origin of the extra chromosome in Trisomy 21 as indicated by analysis of DNA polymorphisms. *The New England Journal of Medicine* 1991; 324(13): 872-876.

Behrman, R., W. Nelson, et al. Nelson Textbook of Pediatrics, 14th Edition. (Philadelphia: W.B. Saunders Company, 1992). pp. 282-284.

BEIR V: Health Effects of Exposure to Low Levels of Ionizing Radiation. Committee on the biological effects of ionizing radiation. National Academy Press. Washington, D.C. 1990. pp. 65-97.

Bingay, E., Wilber, N. Massachusetts Congenital Anomaly Surveillance Pilot Project: Interim Data Presentation. Office of Statistics and Evaluation, Massachusetts Department of Public Health. June 1995.

Bound, J., B. Francis., and P. Harvey. Down's syndrome: prevalence and ionizing radiation in an area of northwest England 1957-1961. *Journal of Epidemiology and Community Health.* 1995; 49: 164-170.

Boyd, N., et al. Dietary fat and breast cancer risk: the feasibility of a clinical trial of breast cancer prevention. *Lipids.* 1992; 47(10): 821-826.

California Birth Defects Monitoring Program. *Birth Defects in California, January 1, 1983-December 31, 1986*. California Department of Health Services and March of Dimes Birth Defects Foundation. January 15, 1990.

CAN. Topographic map of the Albany, N.Y., Conn., Mass., NH, VT. area produced by Hubbard Scientific Inc. 1974. provided to the Massachusetts Department of Public Health by the Citizens Awareness Network (CAN). CAN Deerfield River Health Committee, February 7, 1996.

Claude, S., et al. Epidemiology of Down syndrome in 118,265 consecutive births. *American Journal of Medical Genetics Supplement*. 1990; 7: 79-83.

Cobb, S. Health in the Deerfield River Valley: some preliminary looks. *Unpublished*. September 29, 1992.

Czeizel, A., et al. Environmental trichlorfon and cluster of congenital abnormalities. *The Lancet*. 1993; 341: 539-542.

Dawson-Saunders, B. and R. Trapp. Basic and Clinical Biostatistics. 2nd Edition. (Norwalk, Connecticut. Appleton and Lange, 1994). pp. 50.

Dellarco, V., P. Voyteck, A. Hollaender. Proceedings of the Symposium on, Aneuploidy: Etiology and Mechanisms. Washington, D.C. March 25-29, 1985. (New York, Plenum Press, 1985) pp. 33, 117, 133-164, 539-548.

Edmonds, L. Personal Communication. May, 1996.

Emery, A. and D. Rimoin. Principles and Practice of Medical Genetics. 2nd Edition, Vol. 2 (New York: Churchill Livingstone, 1990). pp. 1923-1929.

Evans, H. J., M.F.Lyon, and A. Czeizel. Is the incidence of Down syndrome increasing? ICPEMC Meeting Report No. 3. *Mutation Research*. 1986; 175: 263-266.

Falck Jr., F., et al. Pesticides and polychlorinated biphenyl residues in human breast lipids and their relation to breast cancer. *Archives of Environmental Health*. 1992; 47(2): 143-146.

Freedman, A. and L. Nadler. Malignant Lymphomas. In: Harrison's Principles of Internal Medicine, 13th ed., vol. 2. K. Isselbacher, Ed. (New York: McGraw-Hill, Inc. 1994).

Hansen, B., G. Frederick, and L. Toler. Hydrologic Data of the Deerfield River Basin, Massachusetts. Massachusetts Hydrologic-Data Report No. 13. United States Department of the Interior Geological Survey: Prepared in cooperation with The Commonwealth of Massachusetts, Water Resources Commission, 1973.

Harjulehto-Mervaala, T., et al. The accident at Chernobyl and trisomy-21 in Finland. *Mutation Research*. 1992; 275: 81-86.

Harlap, S. A time-series analysis of the incidence of Down's syndrome in West Jerusalem. *American Journal of Epidemiology*. 1974; 99(3): 210-217.

Harlap, S. Down's syndrome in West Jerusalem. *American Journal of Epidemiology*. 1973; 97(4): 225-232.

Hassold, T., P. Hunt, and S. Sherman. Trisomy in humans: incidence, origin and etiology. *Current Opinion in Genetics and Development*. 1993; 3: 398-403.

Henderson, IC. Breast Cancer. In: Isselbacher, K., et al, Eds. Harrison's Principals of Internal Medicine. 13th ed., vol. 2. (New York: McGraw-Hill, Inc. 1994). pp. 1840-1850.

Higginson, J., C. Muir, N Munoz, Eds. Cambridge Monographs on Cancer Research. Human cancer: Epidemiology and environmental causes. (Cambridge, England: Cambridge University Press, 1992).

Hook, E. and I. Porter. Population Cytogenetics: Studies in Humans. (New York: Academic Press, Inc., 1977). pp. 285-353.

ICD 9 CM. The International Classification of Diseases, 9th Revision, Clinical Modification. Edwards Brothers, Inc., Ann Arbor, Michigan. 1991.

Janerich, D. and M. Bracken. Epidemiology of trisomy-21: A review and theoretical analysis. *Journal of Chronic Diseases*. 1986; 39(12): 1079-1093.

Johnson, K and Jocelyn, R. Tritium Releases From The Pickering Nuclear Generating Station And Birth Defects And Infant Mortality In Nearby Communities 1971-1988. Atomic Energy Control Board Project No. 7.156.1 Health and Welfare Canada. October 1991.

Jongbloet, P.H. and O.J. Vrieze. Down syndrome: increased frequency of maternal meiosis I nondisjunction during the transitional stages of the ovulatory seasons. *Human Genetics*. 1985; 71: 241-248.

Kahn, et al. Radiological surveillance studies at a pressurized water nuclear power reactor. *U.S. Environmental Protection Agency, Radiochemistry and Nuclear Engineering Branch*. Cincinnati, Ohio. August 1971.

Kelsey, J. and M. Gammon. Epidemiology of breast cancer. *Epidemiol Rev*. 1990; 12: 228-240.

Kelsey, J. and M. Gammon. The epidemiology of breast cancer. *Ca-A J for Clin* 1991, American Cancer Society. 1991; 41: 146-165.

Kleinbaum, D., L. Kupper, and H. Morgenstern. Epidemiologic Research. (New York: Van Nostrand Reinhold, 1982). pp. 19-26.

Kochupillai, N., et al. Down's syndrome and related abnormalities in an area of high background radiation in coastal Kerala. *Nature*. 1976; 262: 60-61.

Last, J. A Dictionary of Epidemiology. 2nd Ed. (New York, Oxford University Press, 1988) pp. 102-103.

MacIntosh, D., S. Lung, and J. Spengler. A preliminary assessment of potential human exposures to routine tritium emissions from the Yankee Atomic Electric Company Nuclear Power Facility located near Rowe, MA. Unpublished. *Harvard University School of Public Health* 1993.

MapInfo, version 3.0 Copyright MapInfo Corporation, 1985-1994. Troy, New York.

March of Dimes. Public health education information sheet: Down syndrome. *March of Dimes, birth defects foundation*. 1996.

Massachusetts Department of Environmental Protection, Bureau of Waste Site Clean up. *List of confirmed hazardous waste sites and locations to be investigated*. Boston, MA; MDEP 1995.

Massachusetts Department of Public Health, Massachusetts Cancer Registry. *Massachusetts Cancer Registry Abstracting and Coding Manual for Hospitals*. 2nd Ed. March 1996.

Massachusetts Department of Public Health. *Cancer Incidence in Massachusetts 1982-1992 City and Town Supplement*. Bureau of Health Statistics, Research and Evaluation. November 1995.

Massachusetts Department of Public Health, Radiation Control Program. *Memorandum from Thomas O'Connell to Robert Hallisey*. April 5, 1993.

Massachusetts Department of Public Health, Bureau of Health Statistics, Research and Evaluation, Bureau of Parent, Child, and Adolescent Health. *Smoking: Death, Disease, and Dollars*. November 1991.

Monson, R. Occupational Epidemiology. (Florida: CRC Press Inc., 1980). pp. 67-73.

MMWR Down syndrome prevalence at birth-United States, 1983-1990. *Morbidity and Mortality Weekly Report*. 1994; 43(33): 617-622.

Naber, J.M., Carl, H., and B. Goodwin. Temporal changes in Ohio amniocentesis utilization during the first twelve years (1972-1983), and frequency of chromosome abnormalities observed. *Prenatal Diagnosis*. 1987; 7: 51-65.

NCRP Report No. 63. Tritium and other radionuclide labeled organic compounds incorporated in genetic material. Recommendations of the National Council on Radiation Protection and Measurements, March 30, 1979.

Otake, M., Schull, W., and J. Neel. Congenital Malformations, Stillbirths, and Early Mortality among the Children of Atomic Bomb Survivors: A Reanalysis. *Radiation Research*. 1990; 122: 1-11.

Paneth, N. and M. Lansky. Congenital malformation clusters in eastern United States. *The Lancet*. October 1980: 808-809.

Peugh, L. Living near a nuclear plant: mother's responses to Down syndrome. Unpublished. *University of Massachusetts, School of Public Health* 1993.

Ramsay, CN., PM Ellis, and H. Zealley. Down's syndrome in the Lothian region of Scotland-1978 to 1989. *Biomed and Pharmacother.* 1991; 45: 267-272.

Robbins, S., R. Cotran, V. Kumar. The Pathologic Basis of Disease. 3rd edition. (Philadelphia: W.B. Saunders Company, 1984). pp. 126-127.

Rothman, K. and J. Boice. Epidemiology Analysis with a Programmable Calculator. Boston: Epidemiology Resources, Inc. 1982.

Rothman, K. and J. Fabia. Place and time aspects of the occurrence of Down's syndrome. *American Journal of Epidemiology*. 1976; 103(6): 560-564.

Sandler, D.P., et al. Cigarette smoking and risk of acute leukemia: Associations with morphology and cytogenetic abnormalities in bone marrow. *JNCI*. 1993; 85(24): 1994-2002.

Schottenfeld, D. and J. Fraumeni. Cancer Epidemiology and Prevention. (Philadelphia: WB Saunders Company, 1982). pp. 855-867.

Shottenfeld, D. and J. Fraumeni. Cancer Epidemiology and Prevention. (Oxford University Press, 1996).

Schupf, N., et al. Increased risk of Alzheimer's disease in mothers of adults with Down's syndrome. *The Lancet*. 1994; 334: 353-356.

Sever, L., et al. The prevalence at birth of congenital malformations in communities near the Hanford site. *American Journal of Epidemiology*. 1988; 127(2): 243-254.

Sever, L., et al. A case-control study of congenital malformations and occupational exposure to low-level ionizing radiation. *American Journal of Epidemiology*. 1988; 127(2): 226-242.

Sheehan, P. and I. Hillary. An unusual cluster of babies with Down's syndrome born to former pupils of an Irish boarding school. *British Medical Journal*. 1983; 287: 1428-1429.

Singh, I. Season of birth in Down's syndrome. *BJCP*. 1995; 49(3): 129-130.

Simpson, J., et al. Genetics in Obstetrics and Gynecology. (New York: Grune & Stratton, 1990). pp. 53-64.

Skarin, A., et al. Lymphoma. In: Cancer Manual, 8th ed. R. Osteen, Ed. (Boston: American Cancer Society, Massachusetts Division, 1990).

Sperling, K., et al. Significant increase in trisomy 21 in Berlin nine months after the Chernobyl reactor accident: temporal correlation or causal relation? *British Medical Journal*. 1994; 309: 158-162.

Strigini, P., et al. Effect of x-rays on chromosome 21 nondisjunction. *American Journal of Medical Genetics Supplement*. 1990; 7: 155-159.

Troya, M., B. Ondine, P. Bertrand, E. Papiernik, and A. spira. Relationship between the characteristics of the menstrual cycle and congenital malformations in the human. *Early Human Development*. 1985; 11: 307-315.

Ujeno, Y. Epidemiological studies on disturbances of human fetal development in areas with various doses of natural background radiation: Relationship between incidence of Down's syndrome or visible malformation and gonad dose equivalent rate of natural background radiation. *Archives of Environmental Health*. 1985; 40(3): 177-180.

US Department of Commerce. 1980 Census of Population: General Population Characteristics Massachusetts, Washington DC: US Govt. Printing Office.

US Department of Commerce. 1990 Census of Population: General Population Characteristics Massachusetts, Washington DC: US Govt. Printing Office.

U.S. Environmental Protection Agency. Toxics Release Inventory. 1994.

Videbech, P. and J. Nielsen. Chromosome abnormalities and season of birth. *Human Genetics*. 1984; 65: 221-231.

Vincent, V., et al. Pregnancy termination because of chromosomal abnormalities: A study of 26,950 amniocenteses in the Southeast. *Southern Medical Journal*. 1991; 84(10): 1210-1213.

Yankee Atomic Electric Company. Yankee Rowe Effluent and Waste Disposal Report. Annual and Semi-Annual Reports dated 1983 through 1990.

Yoon, et al. Advanced Maternal Age and the Risk of Down Syndrome Characterized by the Meiotic Stage of the Chromosomal Error: A Population-Based Study. *Am. J. Hum. Genet*. 1996; 58: 628-633.

Wald, N. Smoking and leukemia. *British Medical Journal*. 1988; 297: 638-639.

Willis, C. NRC staff evaluation of "Health in the Deerfield River Valley: some preliminary looks." *Unpublished*. NRC 1994.